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# Evaluation and Validation of BODPOD Body Scan Method as Compared to DEXA, Effect of Calcium and Caloric Intake in Female Collegiate Track Athletes

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**Evaluation and validation of BODPOD body scan method as compared to DEXA, effect of calcium and caloric intake in female collegiate track athletes**

**by**

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## ABSTRACT

**Purpose:** This study was conducted to evaluate the validity of the BODPOD air displacement plethysmography as compared to the DEXA (dual energy x-ray absorptiometry) in testing body fat percentages in female collegiate runners. The link between caloric intake and body fat distribution, as well as the link between calcium and vitamin D intake and bone density was also evaluated.

**Methods**: Participants were 8 female collegiate athletes from the USU track team. A 3-day diet history was obtained from each participant and body fat test were performed using both the BODPOD and the DEXA scans within a four month period due to scheduling problems. Results from the diet history were evaluated using the Food Processor SQL and correlations were calculated using SPSS. Information regarding the regularity of their menstrual cycles as well as incidence of stress fractures were also obtained in an interview.

**Results**: There was a correlation between the BODPOD and the DEXA scans (R = 0.731, P = 0.04). BODPOD varied by as much as 6.7% from the body fat results recorded using the DEXA. The median difference between body fat composition measured by the BodPod and DEXA scan was 3.7 (SD)%. Depending on the needs of the user, this value may be problematic. There was no association between caloric intake and body distribution or calcium and vitamin D intake and bone density because of the small sample size and low variability.



**KEYWORDS:** BODPOD, DEXA, female collegiate runners, caloric intake, body fat distribution, calcium, vitamin D, bone density.

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## Objective

To describe the variability in body composition of female athletes when assessed using two methods, dual energy X-ray absorptiometry (DEXA) and air-displacement plethysmography (BODPOD). Observe whether or not there is an association between caloric intake and body fat distribution among participants, as well as calcium and vitamin D intake and bone density.

## **Introduction**:

Excess body fat is associated with many chronic diseases and may also have a large impact on athletic performance.   It is very important that tests that are used to determine body fat be accurate both to assist in guiding the training of athletes in and out of the competitive season (1), as well as to identify and reduce the prevalence of obesity and other major health concerns (2).  The correct assessment of body fat percentages is necessary for a better understanding of diseases associated with too little or too much body fat (3).

There are four main body composition tests used in the general population; bioelectrical impedence analysis (BIA), hydrodensitometry, air displacement plethysmography (BODPOD), and  Dual energy X-Ray (DEXA).

Bioelectrical impededence analysis measures the body impedance with a low level 50-KHz current conducted through the tissues.  Because the fat-free mass contains electrolytes, it behaves like an electrical conductor with electric properties highly dependent on the ionic states, or the mobility and concentration of ions.  In several studies it was found that the BIA method, when compared to hydrodenstiometry or hydrostatic weighing was found to overestimate fatness in lean males and underestimate fatness in overweight subjects (4).  This method is not highly used at the present.

Hydrodensitometry is the most widely used method for estimating % body fat, and has been shown to have an error of only ~2-3% (5).  Hydrodensitometry estimates body volume by weighing an individual underwater (UWW).  Body density is then estimated by dividing body weight (out of water) by body volume.  Density is subsequently  converted into % body fat from which fat mass and fat free mass can be calculated. In this method of calculating body composition it is assumed that fat free mass is at a constant hydration level of 73% (5).

Because of limitations like variations in the proportion of water in the fat-free mass from population to population, hydration status, ratio of protein to mineral and altered bone mineral density, hydrodensiometry may not be appropriate for special population sub groups (4). This variability may be fairly prevalent in female athletes, depending on their training and menstrual histories. Therefore, UWW may not access % body fat accurately in female athletes (5).

The major body fat test used on campus at Utah State University is the BODPOD. A large percentage of USU athletes, as well as the general student population use this equipment each year, and the results are believed to be accurate and valid. The purpose of this study was to compare results from eight female collegiate runners from Utah State University, using both the BodPod and the dual energy x-ray absorptiometry (DEXA) which is thought to be the gold standard in body fat testing and body composition.

Body composition data from the DEXA and 3-day diet histories were obtained from the female participants. Using information from these sources, the linkage between caloric intake/fat intake and body fat distribution is also examined as well as the link between calcium and vitamin D intake and bone density in these athletes with similar activity levels. These measures are important in female athletes because those with very low body fat percentages and low caloric intake paired with strenuous activity may result in the female athlete triad. The female athlete triad results in high bone turnover and a higher risk of forming stress fractures, as well as amenorrhea, or menstrual irregularity (7).

In the study conducted by Beals et al of disorders of the female athlete triad among collegiate athletes, it was discovered that of the 435 female athletes from 7 different universities studied that 43% of the athletes reported feeling terrified of being or becoming overweight, and 55% reported experiencing pressure to achieve and or/maintain a particular body weight. As a result of this fear the study also stated that 67% of these athletes admitted to limiting food choices and severely limiting fat intake and reducing carbohydrate intake (7). The two measures used to assess these athletes are the scale, and a body fat test. It is crucial that tests be accurate when this much pressure is laid on the shoulder of the results.

## METHODS:

Eight female collegiate runners which were recruited from Utah State University participated in this study after giving their informed consent in accordance with procedures established by the Institutional Review Board at Utah State University. The athletic subjects all competed as National Collegiate Athletic Association (NCAA) Division I athletes and participated in sprinting events requiring high levels of physical activity daily.

Five out of the eight participants in this study reported the occurrence of at least one stress fracture in the lower leg/foot region. Three participants also reported amenorrhea within the last year due to high physical activity and minimal caloric intake. This information was obtained from a private interview with each of the participants.

A 3-day diet history (see appendix) was provided to the participants with instruction to fill it out as accurately as possible according to portion size, cooking methods, and types of foods eaten. Participants were also instructed to include two weekdays and one day from the weekend to record their diet histories to best represent their ‘normal” eating habits.

**BODPOD**

Subjects participated in two body fat tests, the first using the BODPODodPod on campus at Utah State University. All subjects were instructed to enter the BODPOD with minimal, body forming clothing including spandex and a sport bra so that results would be more accurate. They were also instructed to have their hair restrained in a pony tail, and a swim cap was worn. After using the restroom, subjects were weighed to the nearest kilogram on a calibrated scale, and height was measured via a stadiometer to the closest centimeter.

To accurately assess an individual's body fat, the BODPOD must first be calibrated. This is accomplished via first running the test with an empty chamber, so that the amount of air contained in the BODPOD may be determined. After each calibration an individual took a seat inside the chamber of the BODPOD. Each participant was instructed to sit still with their hands folded in their lap, and breath normally while their body volume was being calculated. The body density was calculated as

$$Db = Mass/Vbraw + 0.40 - SAA + 40\% \ VTG$$

Where Vbraw = raw body volume, SAA = the surface area artifact and VTG = the thoracic gas volume (3).

**DEXA**

The second body fat test was performed using DEXA, and was performed four months after the BODPOD scans. Participants were required to remove all loose fitting clothing. Scanning using the BODPOD required that participants lay on their backs on the DEXA table . A Velcro strap was used to reduce movement of the lower body and was secured around both feet. Each DEXA scan took approximately three minutes. The DEXA is a "three compartment model which considers total body mineral mass, mineral free mass, and fat mass (1)" DEXA is widely used for measuring bone mineral density, and technological advancements have enabled DEXA to quickly become a preferred method for estimating whole body composition (8).

## DATA ANALYSIS

Information was collected and analyzed for each participant. Eating behaviors were assessed to distinguish between low body fat percentages from a low caloric intake or from a normal caloric intake combined with high physical levels of physical activity. Menstrual status was identified as either eumenorrhea or amenorrhea depending on the length of menstrual cycles occurring every 25-35 days, or cessation of menstruation for three months or more. Individuals who were amenorrheic were marked positive for menstrual irregularities. And individuals with a history of one or more stress fractures in the last 2 years were marked positive for stress fracture occurrence.

Caloric intake was provided through a 3-day diet analysis completed by each participant including portion size, type of food preparation (bake, fry, boil) and type of food consumed. The 3-day diet record included two weekdays and one day from the weekend to try and achieve "average intake" for these individuals, as weekend eating habits tend to differ from those during the week.

Caloric intake was assessed using the Food Processor SQL. Total amounts of the following were calculated from the 3-day period participants recorded their total consumption: kilocalories, carbohydrate, total fat, protein, saturated fat, monounsaturated fat, polyunsaturated fat, trans fat, cholesterol, calcium, vitamin D, phosphorous, vitamin K, iron, sodium, fiber, kilocalories from fat, omega-3 and omega-6.

Because of the small sample size and lack of any clear associations, statistical evaluation of this data using SPSS did not reveal any results when determining any type of correlation between caloric intake or fat intake and body fat distribution; as well as between calcium, vitamin D, vitamin K, phosphorous intake and bone density or stress fracture occurrence. Associations between DEXA and BODPOD scans were calculated using SPSS statistical software.

**RESULTS**

8 out of 10 participant's from Utah State University's track team completed the 3-day diet history for an 80% response rate. 8 out of 10 participants completed both body fat tests, 2 individuals did not participate in the DEXA body scan. 7 out of 10 participants had at least one stress fracture occurring within the last two years. 4 out of ten participants were amenorrheic.

Participants were between the ages of 19 and 25 with a mean age of 21. Mean values for height, weight, body fat, body fat distribution and caloric intake are listed in Table 1. No associations could be made between caloric intake and body fat percentage or body fat distribution because the participant with the highest body fat % had the lowest caloric intake of the group. There also was not any correlation between the different types of fat intake and body fat distribution.

No association was found between calcium, vitamin D and other bone related nutrients and bone density or stress fracture occurrence. According to the statistic run on these variables, the individuals with the lowest calcium intake had the least likely risk of developing a stress fracture, which is completely inconclusive.

There was an association between the BODPOD and the DEXA scans ($R = 0.731$, $P = 0.04$). implying that they measure body fat at a similar rate. The BODPOD measures were off by as much as 6.7% and on average underestimated body fat by 3.7%, with a standard deviation of 2.6 lower body fat. The differences between body composition measures are depicted in figure 1, and healthy standards of body fat percentages are depicted in figure 2. This difference may be attributed to poor calibration of the BODPOD before testing occurred, the 4 month time difference between the two body fat tests, or the BODPOD being an inaccurate measurement of body fat percentage.

**Table 1 Mean values of participants**

| **Characteristic of Participants** | **Mean Value** |
|---|---|
| Height | 5’5’’ |
| Weight | 132 pounds |
| Body Fat % BODPOD | 15.34% |
| Body Fat % DXA | 18.23% |
| Gynoid Fat % | 27.46% |
| Android Fat % | 16.75% |

Figure 1

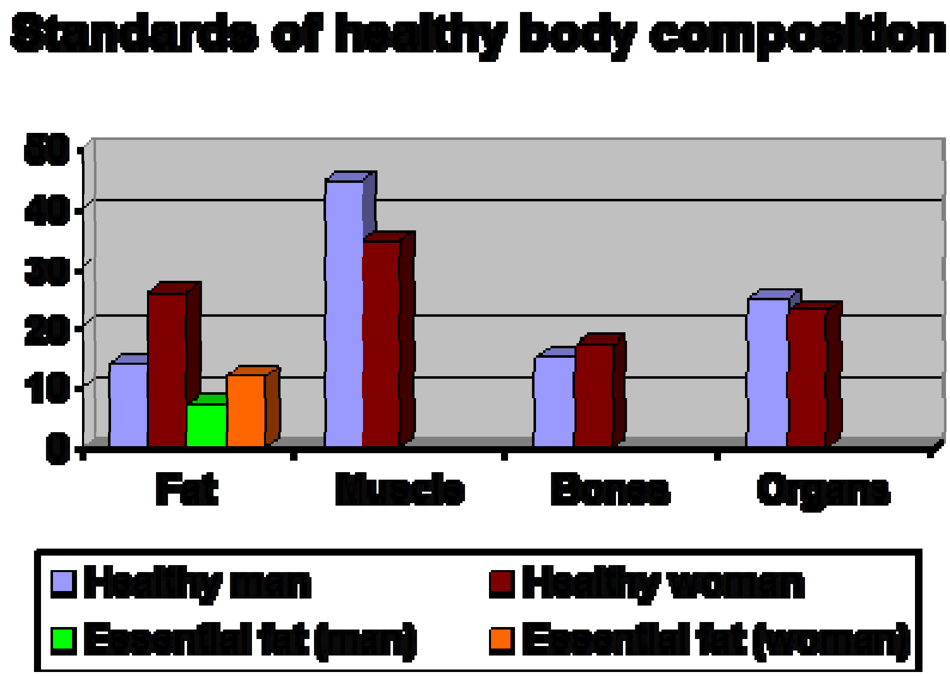



Figure 2

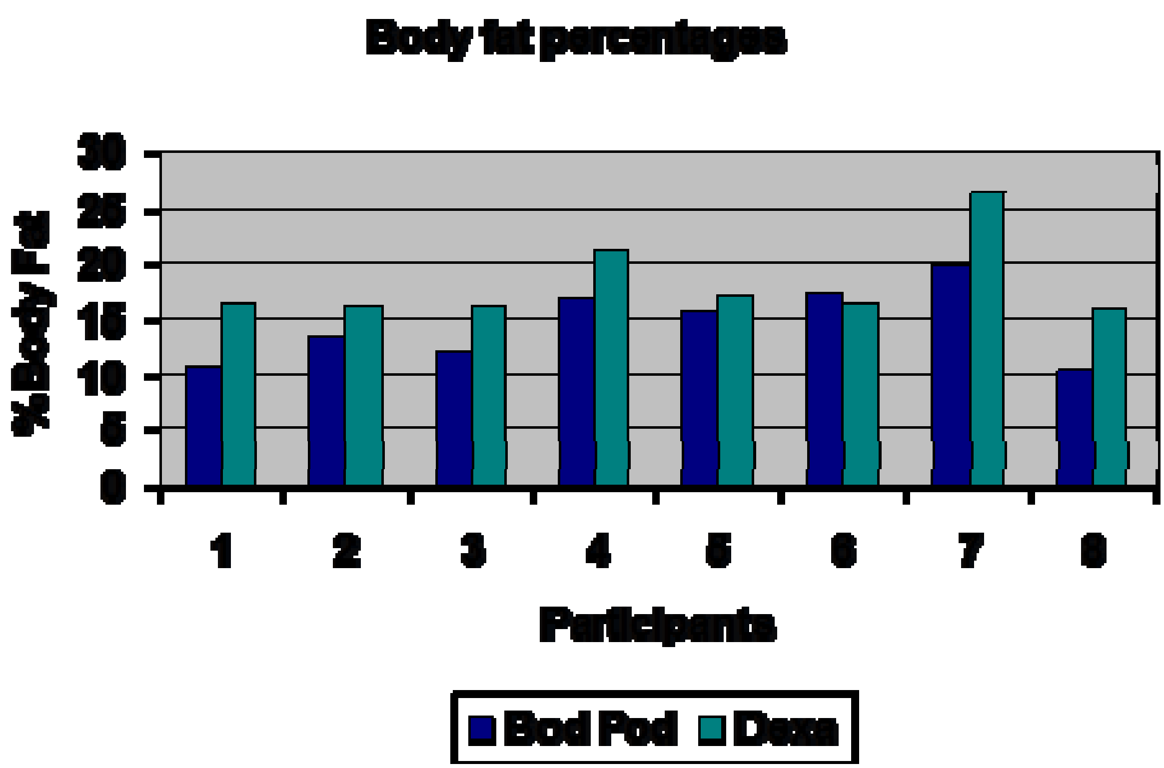
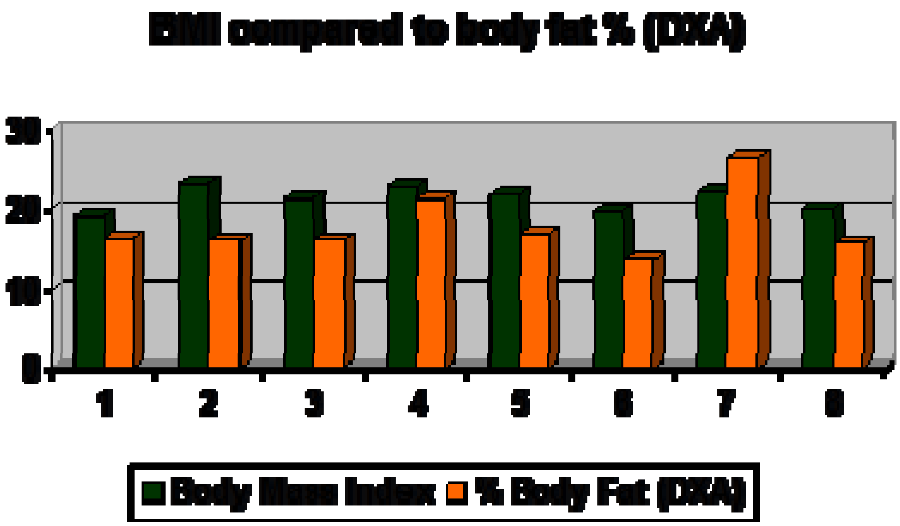


Figure 3




## Conclusion

The group mean for body fat according to DXA was 18.23% with a standard deviation of 3.8. The group mean according to BodPod was 15.34% with a standard deviation of 3.5. The average body fat percentage of a healthy female athlete is 12-20% (1). BodPod results showed a lower body fat percentage than the DXA.

DXA is the gold standard for measuring body composition but use is prohibited due to cost and availability. Due to high cost and accessibility of DXA, BodPod is still a good general measure of body fat as long as the possibility of variability in results is considered. These findings indicate that the BodPod may not be an accurate measurement of body fat percentages among female athletes.

There was no association between caloric intake and body fat distribution, as well between calcium and vitamin D intake and bone density. This is attributed to the small sample size of the participants as well as the low between person variability. A larger sample size is needed and greater between person variation possibly including athletes as well as non athletes.

## Literature Review

Body composition is important in the assessment of nutritional status, disease risk, physical fitness, and effectiveness of interventions (8).  Excess adiposity can alter athletic performance. Athletes often participate in body composition testing to determine the ideal weight that will be competitive for their specific sport. It is important that body composition testing be accurate, reliable readily accessible for a variety of athletes to assist in guiding training both in and out of the competitive season (1).

Traditionally, body fatness has been estimated from measurements of skinfold thicknesses, which correlate reasonably well with body fatness. Concerns have risen over the accuracy of this method because skinfold thicknesses are poorly reproducible (13). Height and weight based measurements are the least expensive, simple and most practical tools for assessing nutritional status. Body mass index (BMI) is the most commonly used method for classifying over-weight and obesity in adults (13). BMI is calculated as body weight in kilograms, divided by height in meters squared ($kg/m^2$).

Technologic developments have allowed for advancements in the field of calculating body composition. Bioelectrical impededence analysis measures the body impedance with a low level 50-KHz current conducted through the tissues. Because the fat-free mass (FFM) contains electrolytes, it behaves like an electrical conductor with electric properties highly dependent on the ionic states, or the mobility and concentration of ions. In several studies it was found that the BIA method, when compared to hydrodenstiometry or hydrostatic weighing was found to overestimate fatness in lean males and underestimate fatness in overweight subjects (4). This method is not highly used at the present, because participants have to hold their breath and be submerged under water for a period of time.

Hydrodensitometry is the most widely used method for estimating % body fat, and has been shown to have an error of only ~2-3% (5). Hydrodensitometry estimates body volume by weighing an individual underwater (UWW). Body density is then estimated by dividing body weight (out of water) by body volume. Density is subsequently converted into % body fat from which fat mass and fat free mass can be calculated. In this method of calculating body composition it is assumed that fat free mass is at a constant hydration level of 73% (5).

Because of limitations like variations in the proportion of water in the fat-free mass from population to population, hydration status, ratio of protein to mineral and altered bone mineral density, hydrodensiometry may not be appropriate for special population sub groups (2). This variability may be fairly prevalent in female athletes, depending on their training and menstrual histories. Therefore, UWW may not access % body fat accurately in female athletes (2).

Air displacement plethysmography (BodPod) is a densitometric method that estimated the fat and fat-free mass via a two component model (14). This system uses the inverse relationship between pressure and volume to determine body volume. Once body volume is determined, the principles of densitometry are used to determine body composition from body density (8). Body density is then calculated as

$$Db = Mass/Vbraw + 0.40 - SAA + 40\%\ VTG$$

Where Vbraw = raw body volume, SAA = the surface area artifact and VTG = the thoracic gas volume (3).

Measurement of body density by air displacement requires determination of the quantity of air in the lungs during normal breathing, or the average thoracic gas volume (11). Therefore, the BodPod needs to calibrate normal breathing in the subject before body composition analysis can be calculated. The chief advantage of the BodPod is that it represents a densitometric method that is based on air displacement rather than on water immersion, it is simpler and more rapid that hydrodensitometry and has wider clinical application (11). There have been problems calibrating the BodPod which may affect the reliability of the results. Another factor that may also effect results is the amount of clothing worn during the body-composition testing. Tight fit clothing is required and hair must be restrained.

Results from a study conducted by Ballard et al, it was discovered that in forty-seven Division II female athletes and twenty-four nonathletes that the BodPod significantly underpredicted body fat when compared with hydrodensitometry and the dual-energy X-ray absorptiometry.

A more valid and precise method for measuring body composition may be dual-energy X-ray absorptiometry (DEXA). DEXA divides the body into three components: bone, fat-free, and bone-free tissue and fat (5). This method is designed to determine bone mineral content and bone mineral density. Studies have also shown that UWW and DEXA agree well at high, moderate and low levels of body fat. The fact that DEXA incorporated bone mineral content when % body fat is being tested may be a major advantage compared to UWW (5). This is important because bone comprises of less than 5% of fat-free mass, but it has the highest density. Changes in bone mineral content can have a great effect on the average density of FFM (5). DEXA is extremely valid and precise for % body fat measurements, but it is very expensive and is found primarily in clinical settings.

Generally high ratios of FFM to fat mass are favorable for an athlete, but too little body fat may result in the deterioration of both health and performance. Optimal body composition varies among individuals in different sports. Some examples of reported values for college-age women include 10-15% for female runners, 15-17% for female gymnasts, and 18-30% for female nonathletes (3).

Accurate body composition assessments are crucial in helping medical personnel in their surveillance of an athlete's physical and mental health. Radical changes in body compositon can be indicative of serious health concerns including the female athlete triad (5). The female athlete triad is the combination of disordered eating, menstrual irregularity, and osteoporosis/osteopenia seen in young female athletes (12).

The female athlete driven to excel in her sport is willing to go to any lengths to achieve success (7). It is now recognized that a substantial proportion of women athletes will develop exercise induced menstrual dysfunction along with other asymptomatic changes that may seriously affect their reproductive physiology and bone metabolism (9). Amenorrhea is the absence of menstrual cycles, characterized by low-circulating estrogens, similar in some ways to the hormonal changes of menopause that lead to accelerated bone loss.

Amenorrhea has long been considered a rather benign side effect of endurance training in female athletes. Amenorrhea in young athletes could place them at a higher risk for clinical osteoporosis later in life (6). Osteoporosis is a disease that is characterized by low bone mass and microarchitectural deterioration of bone tissue. This can lead to enhanced bone fragility and a consequent increase in fracture risk (10). Peak bone mass and subsequent bone loss are important determinants of osteoporosis (15).

Amenorrheic athletes manifest reduced bone density, reduced circulating estradiol and progesterone and increased musculoskeletal injury rates (9). Amenorrhea effects up to 50% of competitive runners (6). It is very important that body composition tests be accurate so that problems associated with too much or too little body fat may be properly accounted for and treated.

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## Author's Biography

Jennifer Day, raised in Layton Utah graduated in 2005 from Layton High school with high honors. She entered Utah State University that fall as an Exercise Science major. After taking a beginning nutrition course her plans changed and she immediately changed her degree to Dietetics. While at Utah State University, Jennifer had the opportunity of participating on the track team and was selected to serve as a captain of the team her senior year.

After she graduates in May, Jennifer plans on completing a dietetic internship through Utah State University. Jennifer will earn a Masters of Dietetic Administration from Utah State University.